

# Performance of the GPS WindEx Real-time Wind Speed Retrieval System during the 2004 Hurricane Season

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# Outline

- Introduction
- Background on GPS reflection technique
- Method for wind speed retrieval
- WindEx hardware-software system
- Results for 2004
- Limitations
- Conclusions

# Introduction

- Project a joint NASA-NOAA effort to demonstrate real time wind speed retrieval.
- Based on use of reflected GPS for wind speed determination.
- Technique originated at NASA-Langley and supported by ESTO from TRL 3→6.
- Consists of GPS reflectometer, real time wind speed processor and intranet server/client Java application.
- Flown on NOAA Gulfstream 4 (N49RF) “Gonzo”
- NOAA assess utility while NASA gains data sets to use for wind direction and high speed regime.

# NOAA's "Gonzo"

(N49RF)



**Ceiling:**

45,000 ft (12 km),

**Range:**

4075 nm (7000 km),

**Endurance:**

10 h

**True air speed:**

440 kt (240 m/s).

**Aircraft**

**dimensions:**

length: 88' 4" (26.9 m)

wing span: 77' 10" (23.7 m)

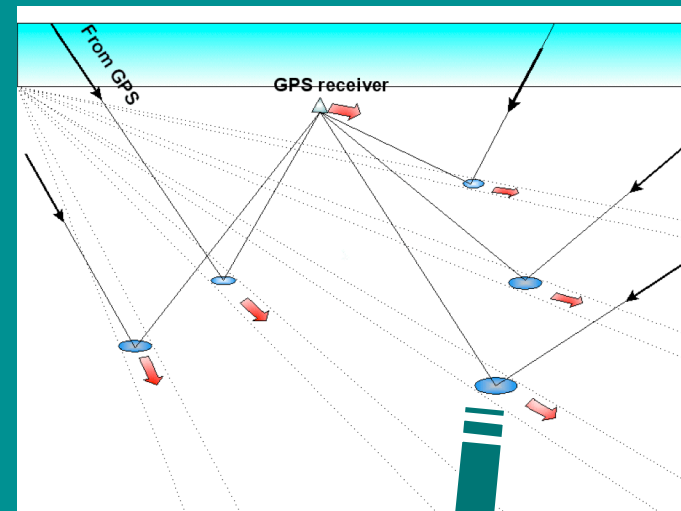
height: 24' 5" (7.4 m)

**Crew:**

10 (3 scientists/observer)

# Background on the GPS technique

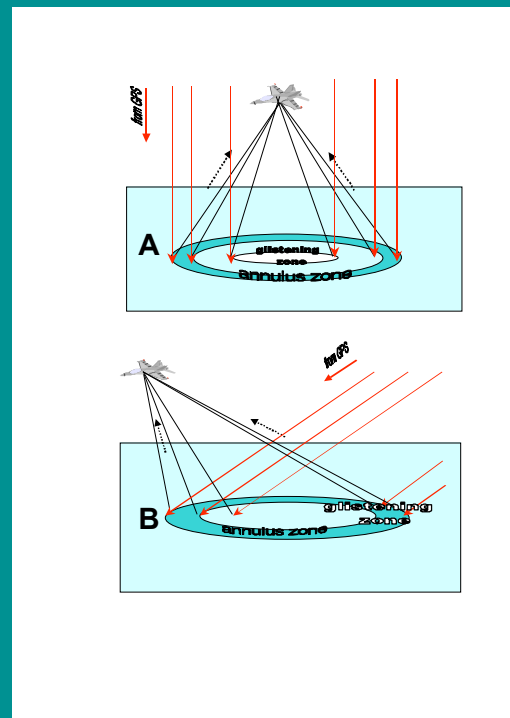
- GPS is L-Band 1.575 GHz
- Water reflectivity is 63%
- Under calm conditions signal appear to arise from couple Fresnel zones near the “specular” point



# Background on the GPS technique

- Specular point is shortest path from surface to receiver
- GPS range coding defines ellipses on surface
- Each ellipse has greater path delay than specular

Scattering geometry in the non-ideal case

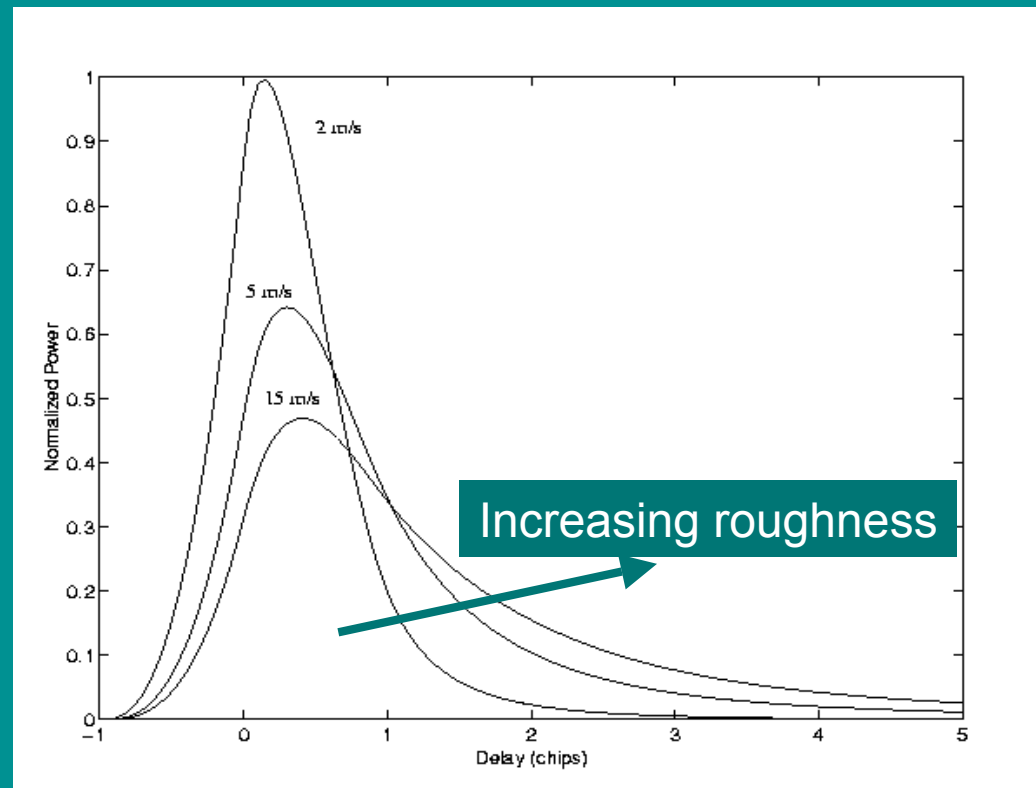


$$a = \frac{\sqrt{2h \sin(\gamma) \delta}}{\sin^2(\gamma)}$$

$$b = \frac{\sqrt{2h \sin(\gamma) \delta}}{\sin(\gamma)}$$

# Background

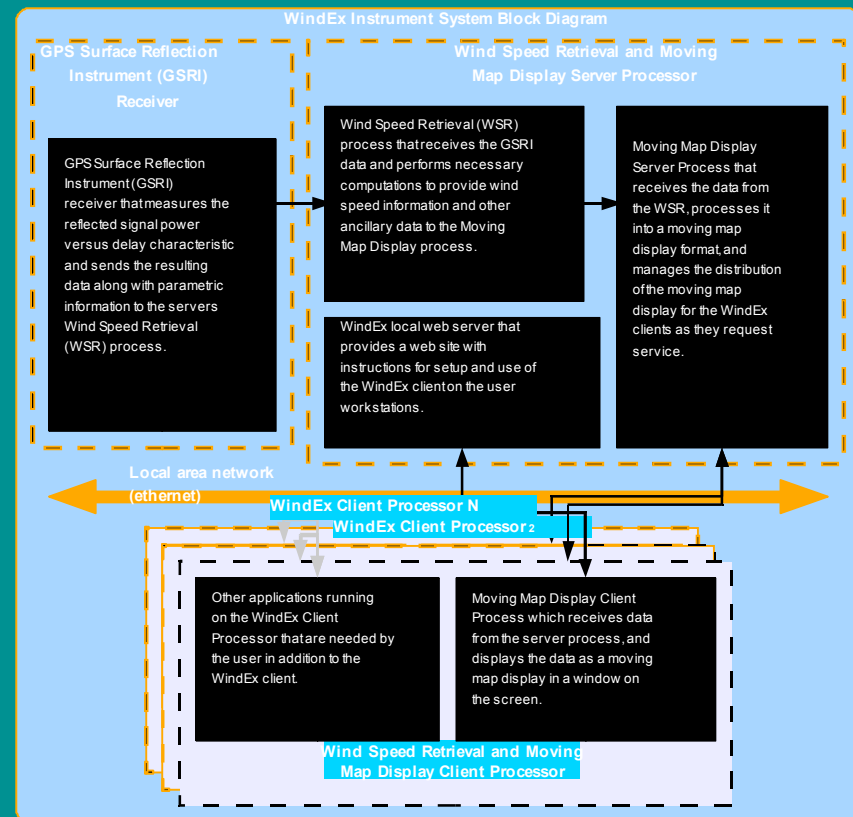
- Wind speed retrieval is based upon knowledge of the surface slope probability density and its convolution with the internal receiver correlation function.
- Using model waveforms, a matched filter is implemented to determine the correct wind speed.



Effect of increasing surface roughness on GPS receiver correlation function

# WindEx Hardware-Software System

- A GPS reflection receiver
- A co-located single board processor hosting:
  - A high rate wind speed retrieval application
  - A network server-client application (Java based)



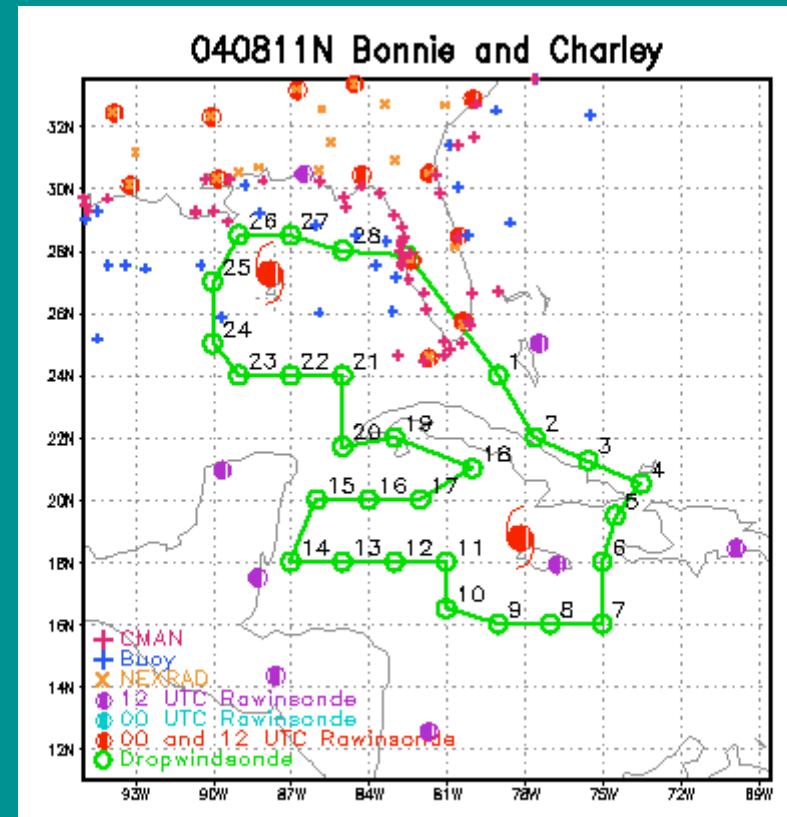


# Results from 2004 Hurricane Season

- Data acquired from Tropical Storm Bonnie, Hurricane Charley, and Hurricane Ivan.
- Dropsondes deployed during G-4 flights serve as surface truth. Data for standard pressure altitudes and surface where possible.
- 15 flights for Ivan, 2 for Charley, and 3 for Bonnie. Some overlap of Bonnie and Charley Flight
- Data for GPS was an average from  $0.1 \times 0.1$  degree around the dropsonde deployment
- If either GPS or dropsonde data was bad, the pair were discarded. Not many like that, but a few.

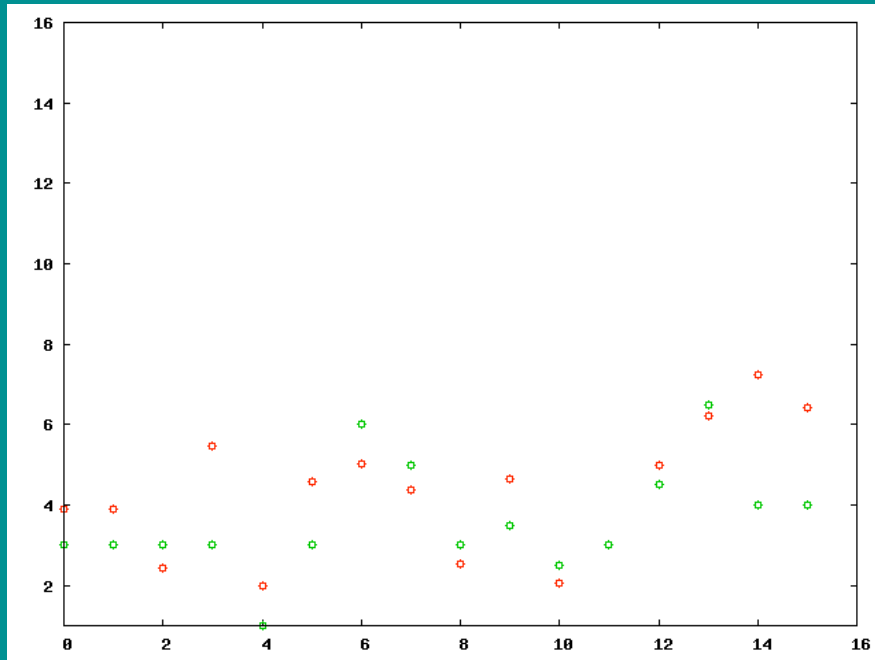
# Results from 2004 Hurricane Season

- Typical example of one of the G-4 flights with overlap of Bonnie and Charley.
- Dropsonde deployment locations.
- Actual locations deviate slightly from those desired.

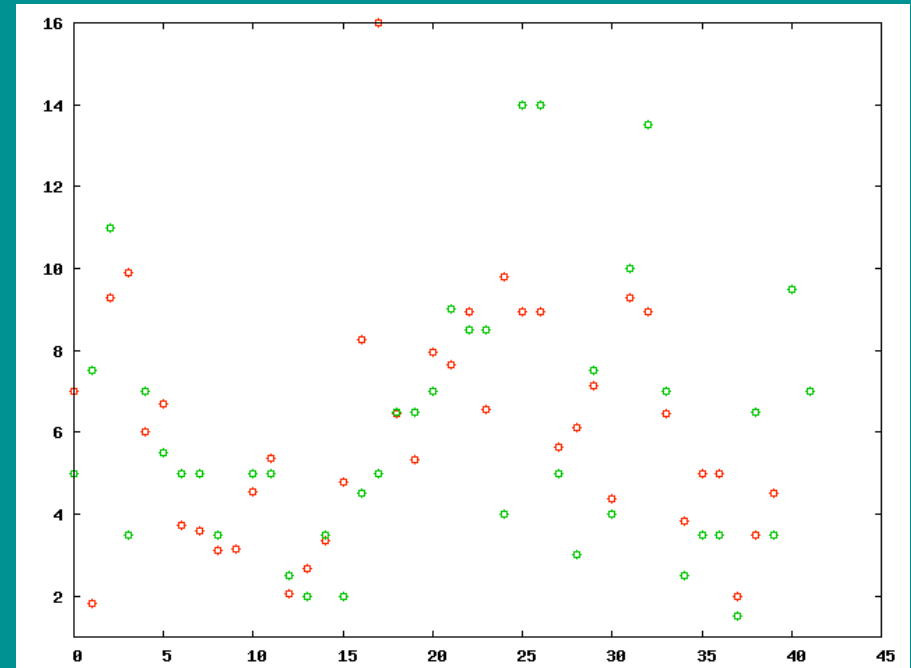


# Results from 2004 Hurricane Season

## *T.S. Bonnie and Hurricane Charley*



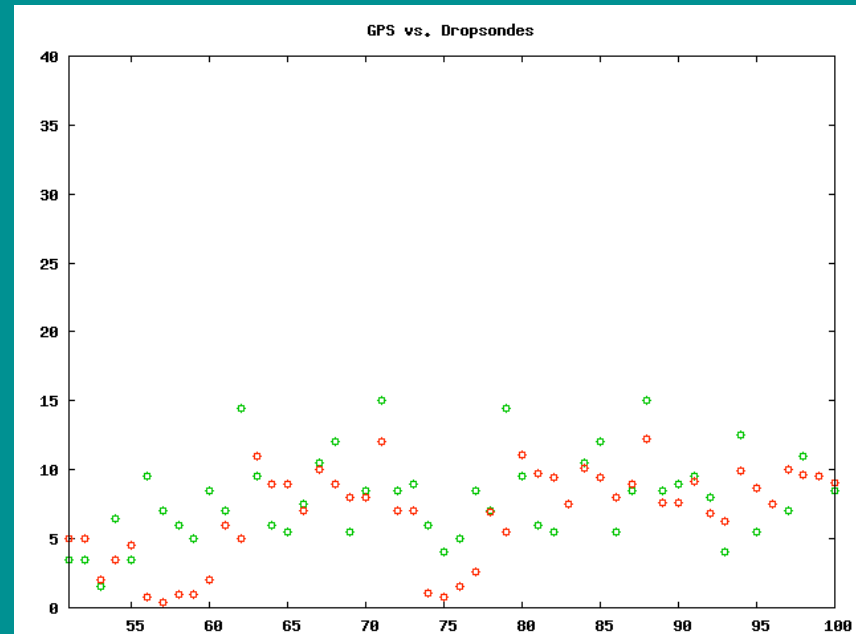
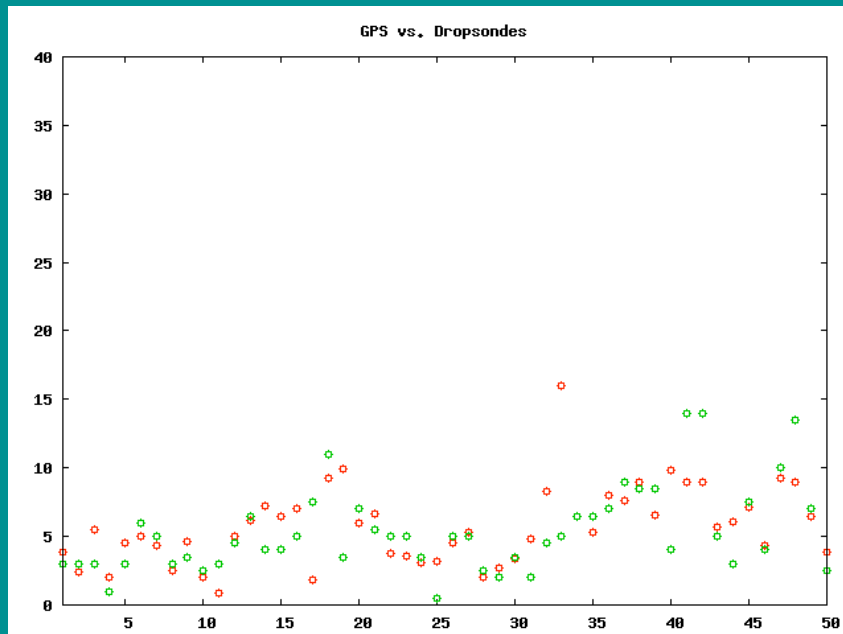
T.S. Bonnie



Hurricane Charley

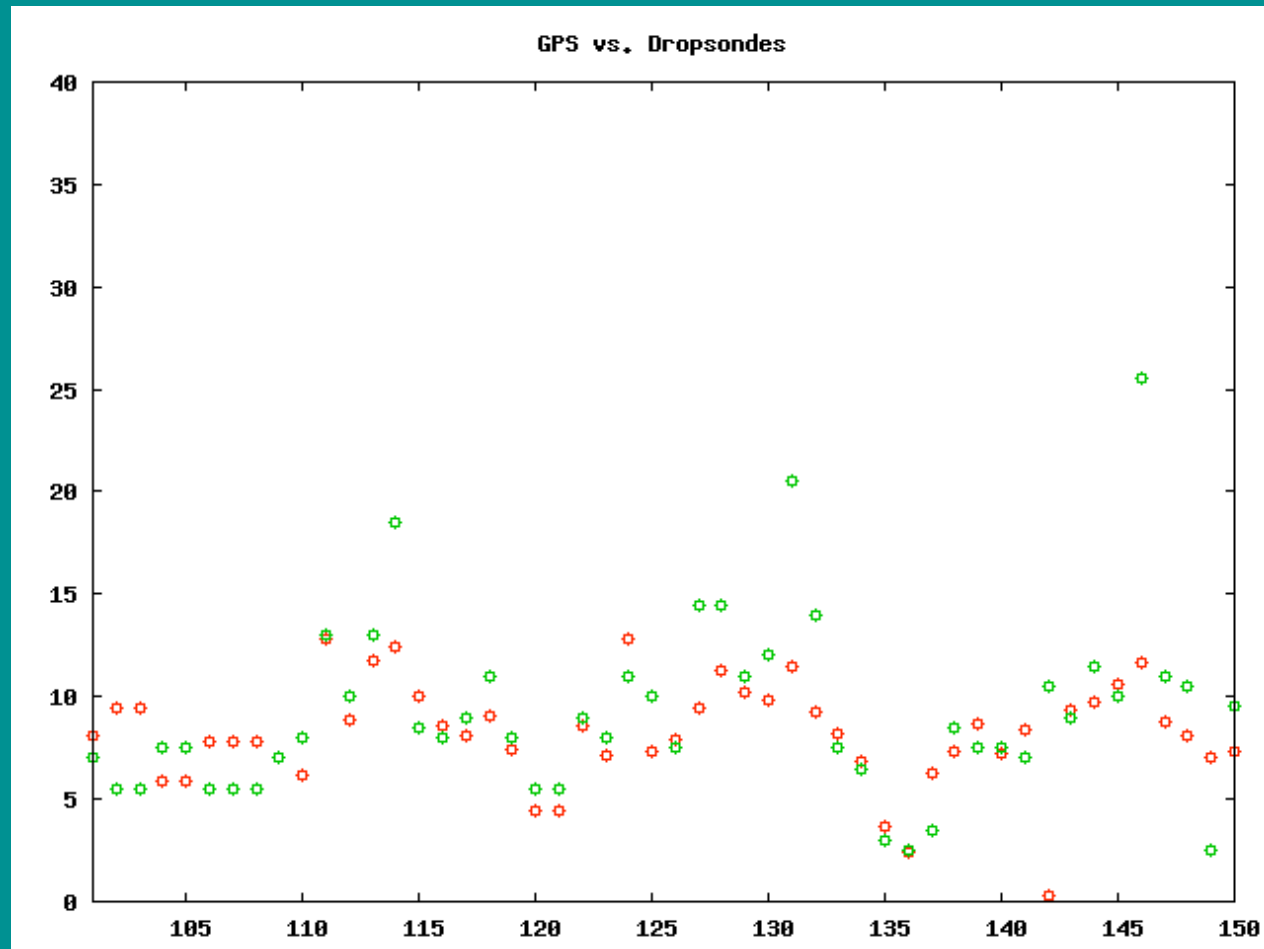
# Results from 2004 Hurricane Season

## *Hurricane Ivan*



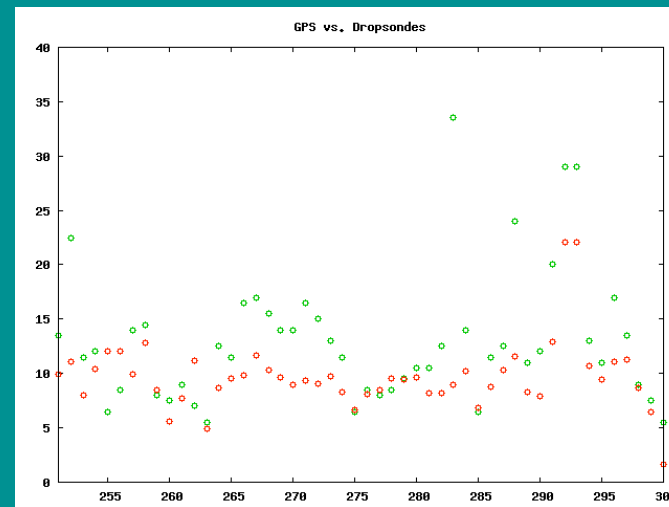
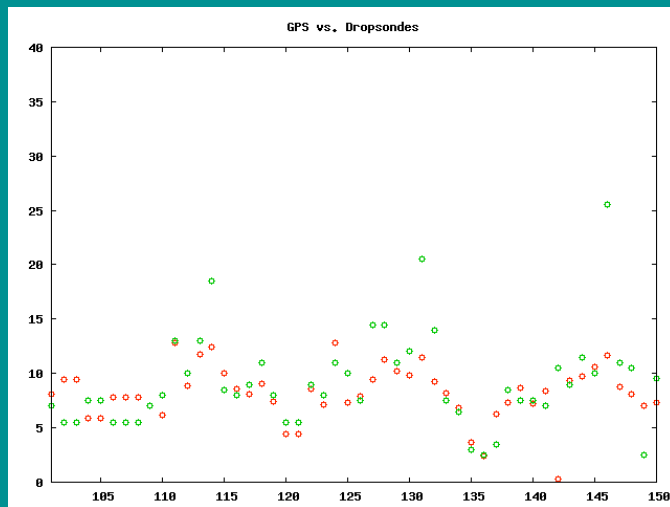
# Results from 2004 Hurricane Season

## *Hurricane Ivan*



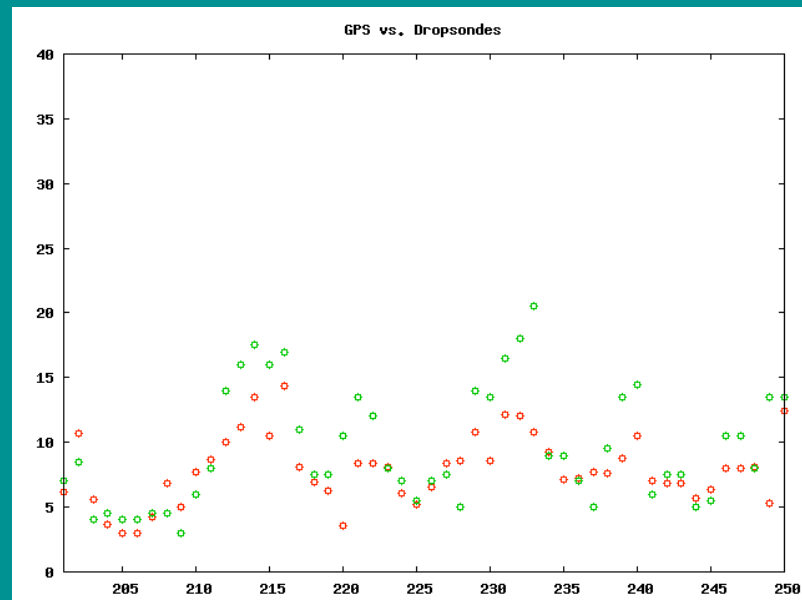
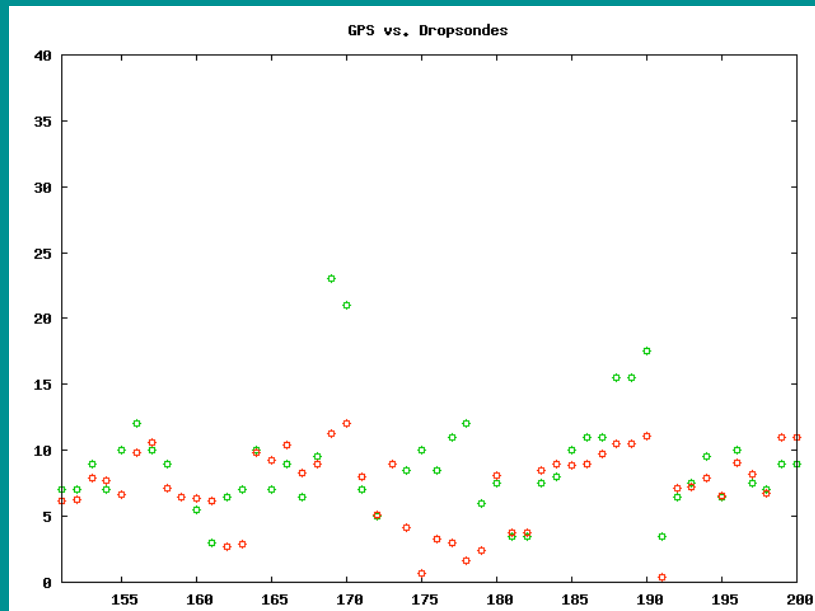
# Results from 2004 Hurricane Season

## *Hurricane Ivan*



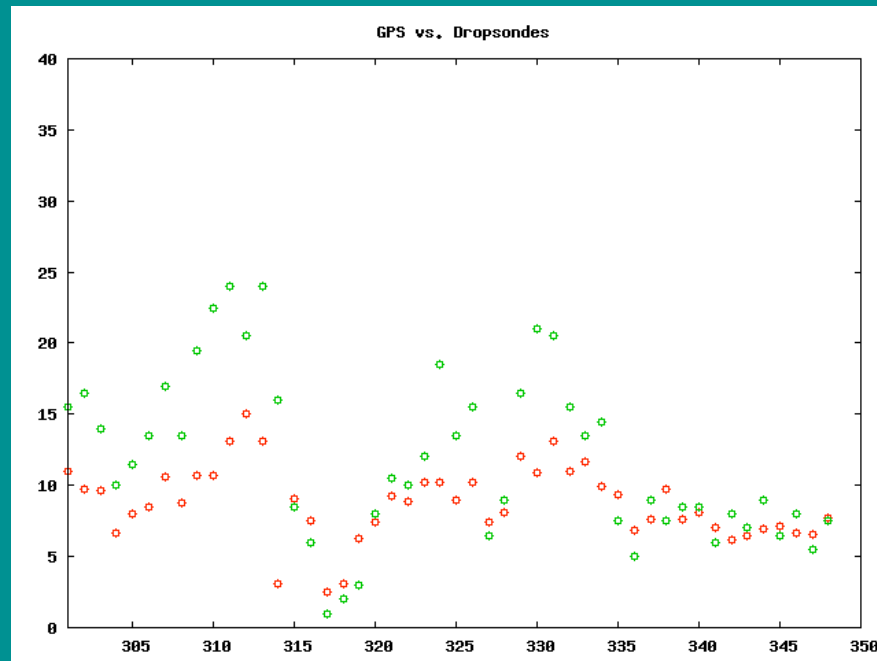
# Results from 2004 Hurricane Season

## *Hurricane Ivan*



# Results from 2004 Hurricane Season

## *Hurricane Ivan*





# Results from 2004 Hurricane Season

- Source of limitation is limitation on number of correlators
- Causes waveform to be truncated ~ to lower wind speed
- Correction: Increase number of correlators
- Patch: Increase the delay bin step size
- Patch will be applied to next upgrade to G-4 system

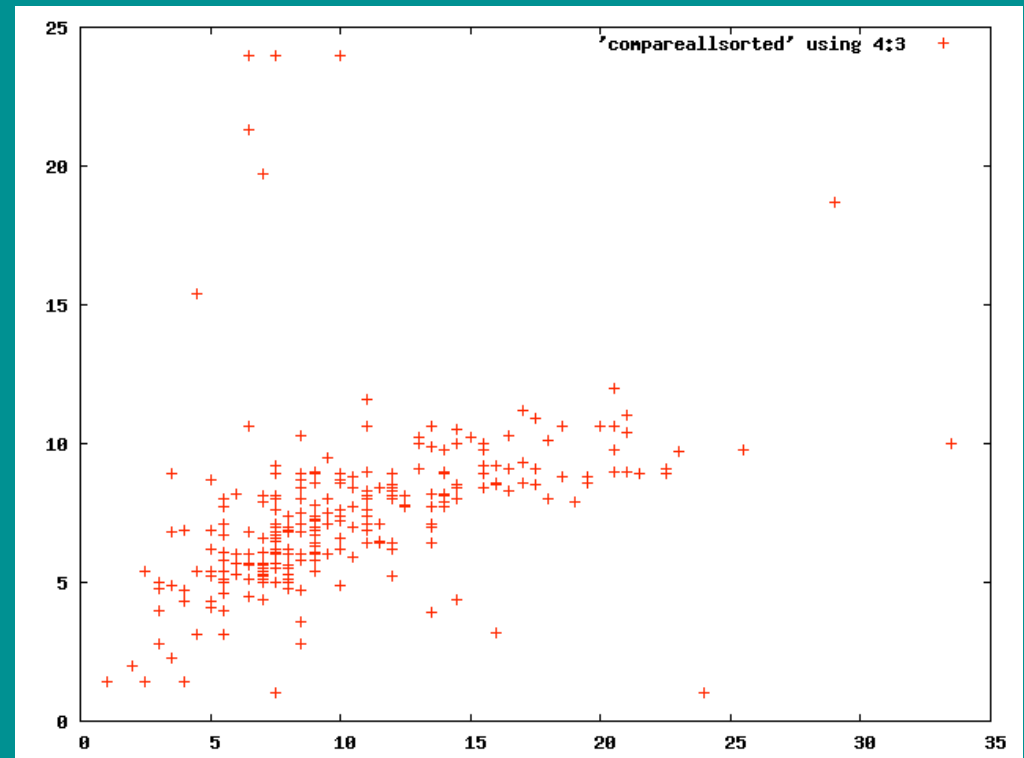


Illustration of saturation for G-4 implementation

# Conclusions

- The use of reflected GPS to determine ocean surface winds in a real time fashion has been successfully demonstrated.
- Minor saturation effects have been noted and will be adjusted to ensure full range of operation.
- Proper fix is improved hardware.
- Ideal for use in expendable UAV's.